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Tests of a Spiro Turbine

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TESTS OF A SPIRO TURBINE

BY

ARTHUR LESLIE MYERS

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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May 31 1913

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Arthur Leslie Myers

ENTITLED Tests of a Spiro Turbine

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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TESTS OF A SPIRO TURBINE

Introduction

Somewhat over a year ago the Buffalo Forge Company placed upon the market a new form of heat motor bearing the trade name of Spiro Turbine. The claims made for this machine were first, its extreme simplicity and ruggedness with attendant low first cost and upkeep; and second, exceptionally good steam economy. This thesis has to do mainly with tests made by the writer upon a 6 h.p. Spiro, kindly loaned the University of Illinois by the manufacturers, for the purpose of investigating the claim as to steam economy. The first claim is manifestly justified as the following description and discussion will show.

CHAPTER I

Description of Turbine.

1. Essentially, the turbine consists of two rotors, a casing in which the rotors revolve, and the heads containing the bearings. Fewer than 100 parts, counting every screw and nut, enter into the construction of this machine. In Fig. 1, are shown the rotors, consisting simply of a pair of herringbone or helical gears cut on special automatic machines and ground to mesh very closely after they are pressed and keyed on to nickel steel shafts. The factor of safety for the load carried by the teeth is claimed to be 40. Fig. 2 illustrates the casing. The two holes on either side of the central rib at the bottom represent the steam inlet ports, and exhaust is through the large port directly above. The rotors are thus partially floated by the steam pressure which is greatest underneath, gradually decreasing around the sides to the top. In this way, friction with consequent wear on the bearings, is lessened. The clearance between the teeth and the casing is very small.

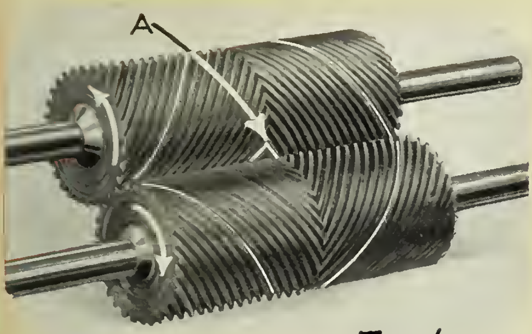

Fig. 1

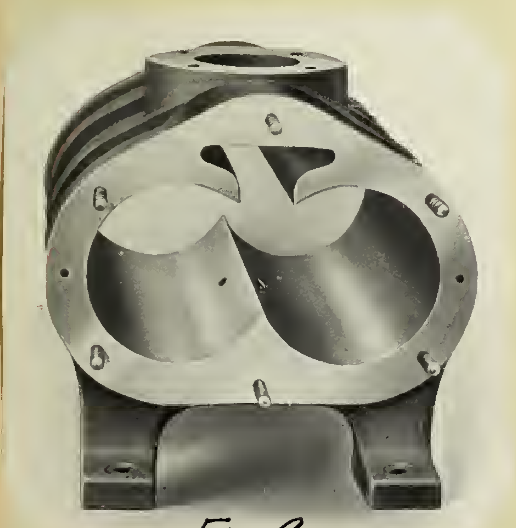

Fig. 2

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The heads which contain the bearings and packing glands are shown in Fig. 3. A sectional view of the usual bearing is seen in Fig. 4, while Fig. 5, page 4, shows the packing gland which effectually prevents the leakage of steam through the heads. The problem of leakage is fairly simple since the ends of the rotors, and hence the heads, are subject to exhaust pressure only. In the turbine tested, ball bearings, lubricated from external grease cups, replaced the type mentioned. There is no end thrust since each rotor consists of two opposed gear sections. The film of steam between the teeth and casing forms a cushion, preventing friction, but the use of a lubricator, feeding cylinder oil rather slowly, has been found to give the best results.

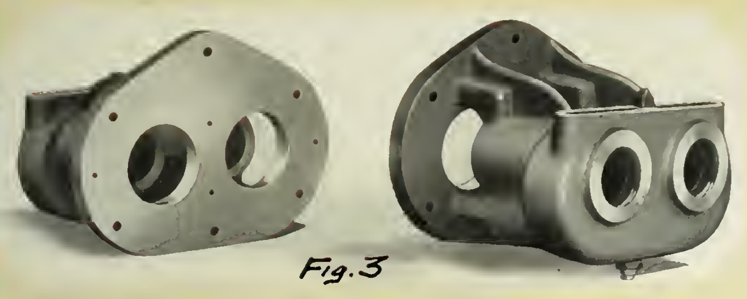

Fig. 3

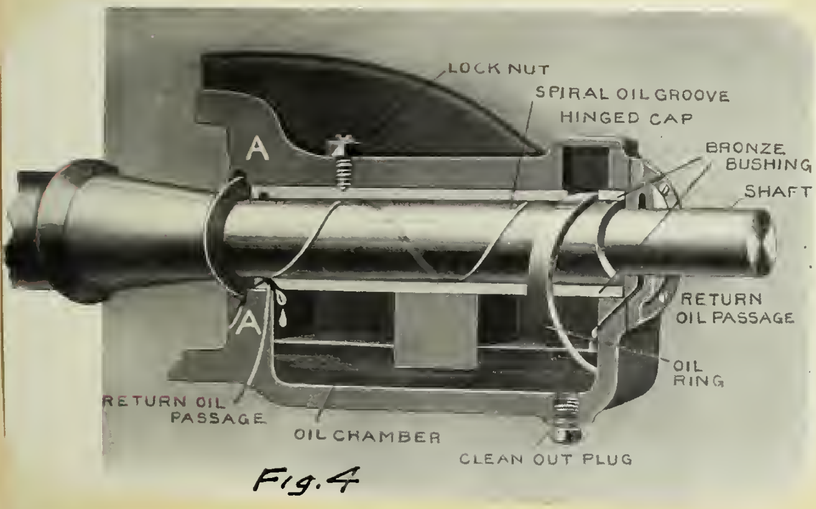
LOCK NUT
SPIRAL OIL GROOVE
HINGED CAP
A
BRONZE BUSHING
SHAFT
A
RETURN OIL PASSAGE
OIL RING
RETURN OIL PASSAGE
OIL CHAMBER
CLEAN OUT PLUG

Fig. 4

A very good idea of the great simplicity of the machine can be gained by a study of Fig. 6, page 4, which shows a phantom view.

From a consideration of the foregoing, it is readily seen that the turbine is exceptionally simple in design, and with ordinary care should last indefinitely. The entire absence of intricate parts helps to bear out this statement.

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Dimensions of Turbine, etc.

a.Floor Space: 20" x 26"

b.Diam. Inlet Pipe: 3/4"

c. " Exhaust " : 2"

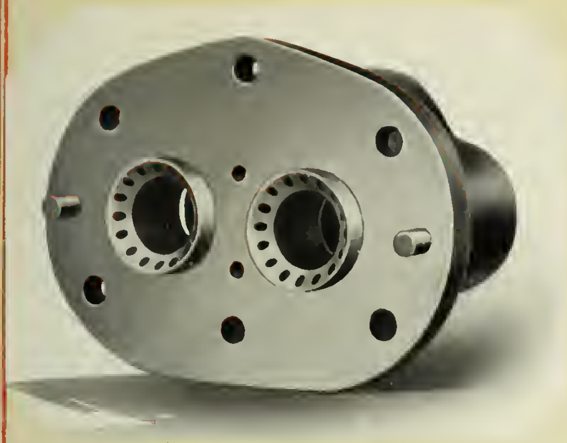
d.Size of Rotors: 3-1/2" x 8-7/16",approx.

e.Weight of both Rotors, mounted on Shafts: 43.25 lb.

f.Teeth on each Rotor:

  1.Number:- 16
  2.Size:- Face: 1/8", approx.
  Base: 11/32" "
  Depth: 9/32" "

g.Inlet Ports: 1/2" long, somewhat elliptical in shape.



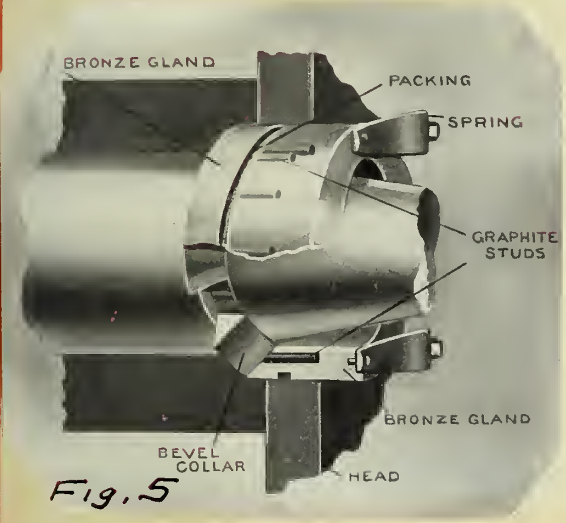

BRONZE GLAND
PACKING
SPRING
GRAPHITE STUDS
BRONZE GLAND
BEVEL COLLAR
HEAD

Fig. 5

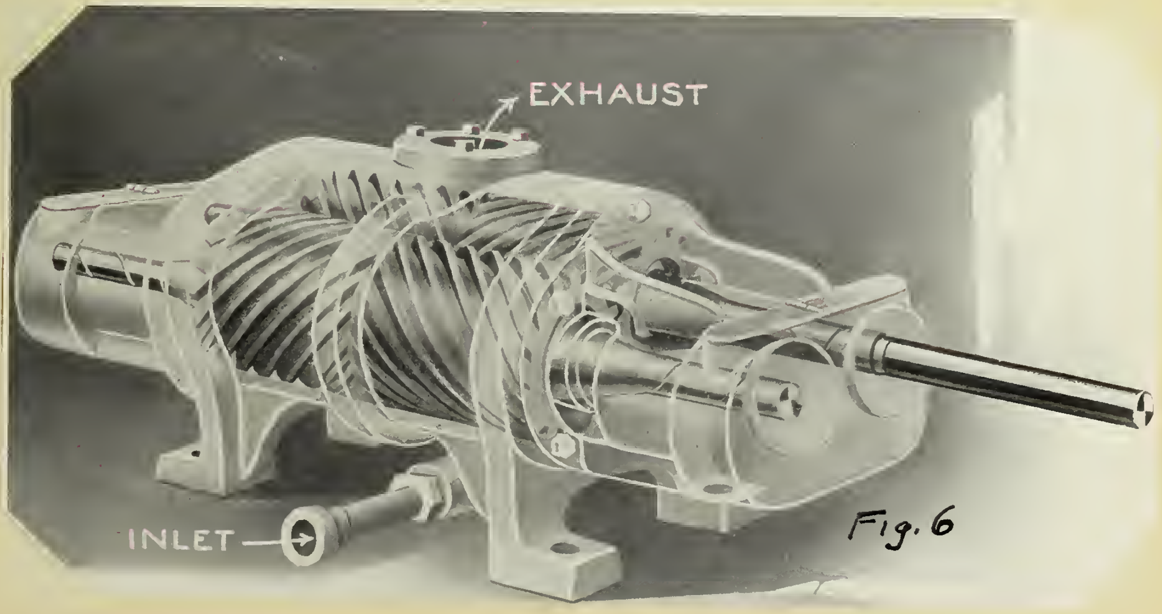

EXHAUST
INLET

Fig. 6

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CHAPTER II

Steam Analysis

2. A brief analysis of the steam action is next in order. Fig. 7 shows a section of the turbine at midlength, with the steam inlet below and exhaust above. The port is so designed that the jet of entering steam strikes the V-shaped pockets, formed by the junction of the two sections of teeth, at right angles with the axes of the rotors and tangent to them. The ports are rapidly covered and uncovered by the teeth, but since the velocity of the steam is greater than that of the rotors, considerable steam under high pressure gets into the immediate tooth space each time a port is uncovered. The steam then passes around the outside of the rotors next to the casing, and out at the top, expanding all the way. The velocity of the steam through the inlet port is not over 300 feet per second, and hence the turbine is really of the pressure type although there is more or less impact as the jet strikes each pocket. The principal reaction resulting in useful work is that which follows from the change of direction of the steam. Entering the turbine at right angles to the axes of the rotors, the jet leaves in a direction practically parallel with the axes, and hence it has been turned through an angle of about 90 degrees. Seemingly, there is no work

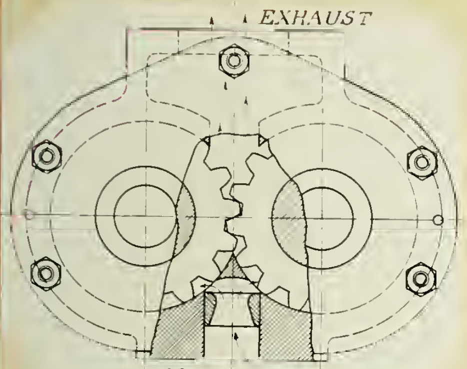


Fig. 7

ow.

emp

accomplished by the expansion of the steam. In fact, it would appear that the friction involved in the passage of the steam through the long tooth spaces would detract from the efficiency of the machine. It is claimed by the manufacturers that with a ratio of expansion of 3-1/2 (which is commonly employed), and an initial pressure of 100 lb., the terminal pressure is about 7 lb., taking into account the drop through impact. This low exhaust pressure, resulting from expansion, is of course desirable since it simplifies packing, and other problems.

If it is true, therefore, that the steam does not do useful work in expanding, then exceptionally good economies cannot be looked for in connection with this machine.

CHAPTER III

Preparation for the Tests

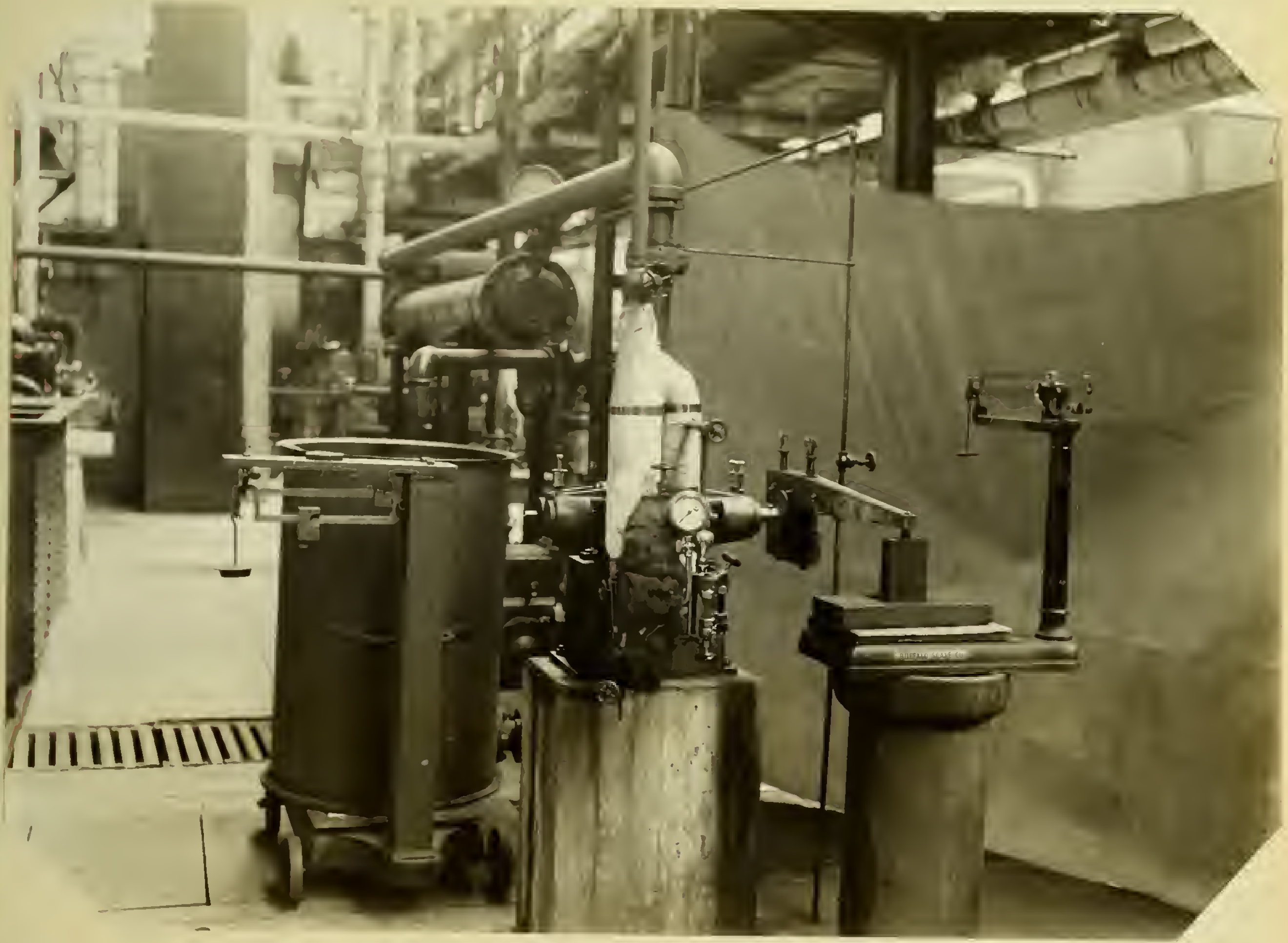
3. The Dynamometer. It was not anticipated that a great deal of time would be required in getting ready to test the turbine, but several difficulties were encountered which resulted in delay after delay. The Buffalo Forge Company recommended the use of various sizes of blast wheels as absorption dynamometers, and it was the intention to calibrate these by means of an electric motor. The wheel was to be fastened to the motor shaft and the power input and efficiency determined. Then calibration curves were to be drawn, plotting horse power against speed, correcting for barometer, humidity, and temperature. This plan had to be abandoned when it was found that no motor of sufficiently high speed was available. The only reasonable alternative seemed to be the use of a prony brake, and considerable doubt was expressed as to the advisability of its use with speeds of 2000 to 4000 r.p.m. The writer designed and constructed a brake, attempting to make the pulley as light and well balanced as possible so as not to cause vibration at high speeds, and with a very thin shell which would readily transmit the heat of friction to the cooling water. The face of the pulley was 2-1/2" with a diameter of 4-1/2". A hollow arm extending to one side fitted over the shaft and was secured to the latter by means of four set-

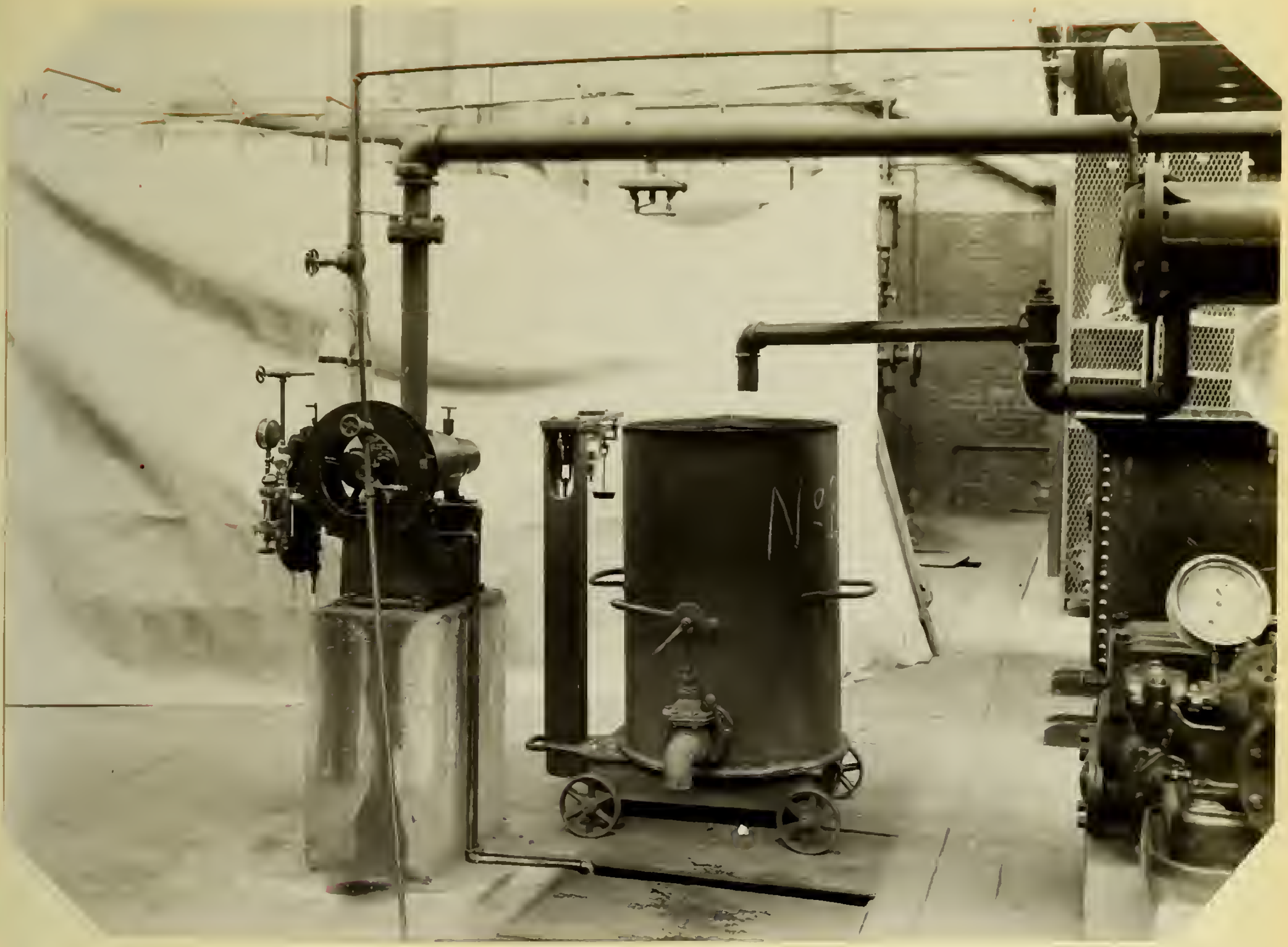
screws. The weight of the pulley was approximately 5 pounds. The wood blocks and arm were of maple, joined by two 1/2" bolts slipped through coil springs so that a relatively delicate adjustment was possible. The length of the arm was 2 feet. A continuous oiler attached to the upper block, feeding a light lubricating oil mixed with graphite, was found to give good results. An idea of the design and appearance of this brake can be gotten by referring to the photograph on page 9. For purposes of comparison, it was decided to use the three blast wheels sent by the Buffalo Forge Company, together with the calibrations submitted by them.

4. The Calorimeter. Since the water rate was to be based on dry steam, it was imperative that the quality of the steam should be accurately determined. It was learned from a few preliminary tests that the quality was too low to permit the use of a throttling calorimeter, and hence a Carpenter separating calorimeter was substituted. In this device the moisture in the steam is mechanically thrown down, due to inertia, and collected in such a way as to permit of measurement. The dry steam escapes from the instrument through an orifice of known size, and the quantity passing through in 10 minutes, depending of course on the pressure, can be read directly from a special steam gage.

5. Other Apparatus. The steam line to the turbine was an uncovered, 1" pipe of some length, and hence the use of a separator was highly desirable. Such a device was constructed of pipe fittings with a drip line below. The lubricator which came with the turbine was also installed in the line. The exhaust connection was taken up

and carried over to a Wheeler surface condenser (cooling surface, 63.5 sq. ft.), whose air pump was out of commission, thus making any vacuum tests impossible. The accompanying photograph shows the arrangement of apparatus when testing with a prony brake, and is a front view of the machine. The photograph on the next page is a rear view with one of the blast wheels replacing the prony brake. Two small pipes are seen leading down from the base of the turbine, one of which is the drip from the separator and the other is an outlet from the turbine for the condensed steam which collects when the machine is idle and which must be allowed to escape before starting.





The scales used in connection with the brake were very sensitive. These, as well as the tank scales and the steam gage, were of course calibrated. The condenser was also tested for leakage by allowing the circulating water to pass through it under a slight pressure. A hand speed counter and an instantaneous tachometer were used to obtain the r.p.m., the latter instrument serving as a check upon the former.

Note: The photograph on page 9 was taken after the oiler was removed and Raybestos lining attached to the blocks.

CHAPTER IV

The Tests

6. Trials of thirty minutes with the prony brake and twenty minutes with the blast wheels were run whenever possible. The first series of tests with the brake, which included all but three of the trials, were run at constant pressures, beginning at 50 lb. ga., up to 90 lb., by 10 lb. increments; and then from 90 lb. up to 115 lb. by 5 lb. increments. It was the idea to keep the speed as constant as possible by adjusting the brake when necessary. The tendency of the brake was to get red hot even when a copious stream of water played upon its interior, and hence it was impossible sometimes to complete a test. When the brake began to get unmanageable, pains were taken to keep the speed and load constant until a convenient time interval was up, when the final observations were taken. The writer was unable, however, to run the turbine at anywhere near its full capacity except on one occasion when Raybestos lining was used on the wood blocks. Even then this material seemed to wear down so rapidly that an attendant was kept busy adjusting the tension between the blocks.

The turbine was always warmed up before a test was run and every effort made to keep conditions constant throughout each trial. This was hard to do, especially when the brake was used. Since the

manufacturers' water rate was based on a gage pressure of 100 lb., zero back pressure, several tests were made as nearly under these conditions as possible.

In connection with the fan tests it was the intention to run at constant speed with a sufficient number of trials to give a comprehensive range, say from 1500 r.p.m. to 3500 r.p.m. Since the speed of each individual fan depended upon the steam pressure alone, no effort was made to keep the pressure constant.

On the following pages will be found log sheets of all tests run, followed by a table and curves showing the results obtained together with a page of sample calculations.

Tests of a Spiro Turbine

A. L. Myers　　Log Sheet No. 1　　May 2, 1913.

Barom. 29.432　Room Temp. 81 F　O. Temp.　Tare on Br.Sc. 5.27 lb.

Calorimeter								Temperatures		
Time	Steam Press. Ga. lb./sq.in.	ω Dry Steam thro' Or. in 10 min.	W lb. water from Sep.	Time	r.p.m.	Wght. on Br. Sc. lb.	Wght. on Tank Scales (Condensate) lb.	Circ. Water Inlet °F	Circ. Water Outlet °F	Hotwell °F
9:23	50.0	3.85	.110	9:25	1600	5.61	131.5	57.0	63.0	98.3
9:33	50.0	3.85	.310	9:30	1580	5.67				
①				9:35	1700	6.40				98.2
9:39	50.0	3.85	.100	9:40	1760	6.30		57.0	63.0	98.2
9:49	50.0	3.85	.310	9:45	2230	6.14				
				9:50	1880	6.22		57.0	63.0	98.7
				9:55	1850	6.22	291.5			
				10:00	1830		176.5			
10:08	60.0	4.45	.130	10:05	1450	7.65		57.0	64.0	101.5
10:16	60.0	4.45	.350	10:10	1350	7.55				
				10:15	1280	7.55				
②				10:20	1480	7.30		57.0	64.0	101.7
10:19	60.0	4.45	.120	10;25	1630	7.30				
10:28	60.0	4.45	.350	10:30	1650	7.32	387.0			
10:41	70.0	5.00	.100	10:35	1900	8.02	214.5	57.0	65.3	104.8
10:50	70.0	5.00	.370	10:40	1980	7.97				
				10:45	1760	8.07		57.0	65.5	105.0
③				10:50	2200	7.95				
10:52	70.0	5.00	.132	10:55	2170	7.85				
10;59	70.0	5.00	.340	11:00	2130	7.80		57.0	66.0	107.5
				11:05	1600	6.75	432.5			
11:13	80.0	5.60	.120	11:10	1860	8.28	186.0	57.0	67.7	111.5
11:18	80.0	5.60	.280	11:15	2200	8.40				
				11:20	2280	8.47				
④				11:25	2400	8.45		57.0	67.7	110.1
11:21	80.0	5.60	.105	11:30	2580	8.50				
11:27	80.0	5.60	.300	11:35	2300	8.60		57.0	67.3	110.7
11:35	80.0	5.60	.150	11:40	2380	8.50	427.5			
11:39	80.0	5.60	.275							
11:47	90.0	6.20	.110	11:45	2370	9.16	171.0	57.0	68.0	114.0
11:52	90.0	6.20	.300	11:50	2640	9.00				
11:56	90.0	6.20	.118	11:55	2350	9.20		57.0	68.0	114.3
12:00	90.0	6.20	.265	12:00	2350	9.17				
12:02	90.0	6.20	.120	12:05	2420	9.10				
12:07	90.0	6.20	.290	12:10	2220	9.25		57.0	67.8	114.2
⑤				12:15	2100	9.00	443.0			

Tests of a Spiro Turbine

A. L. Myers　　Log Sheet No. 2　　May 2, 1913.

Barom. 29.400　Room Temp. 86.5 F　O. Temp. 84 F　Tare on Br.Sc. 5.35

Calorimeter							Temperatures		
Time	Steam Press. lb./sq.in.	W	Time	r.p.m.	Wght. on Br. Sc. lb.	Wght. on Tank Sc. lb.	Inlet °F	Outlet °F	Hotwell °F
2:32	95.0	.120	2:30	2040	9.57	162.0	61.0	73.5	116.5
2:38		.310	2:35	1770	9.60				
2:41	95.0	.130	2:40	2000	9.35				
2:47		.310	2:45	1950	9.30		62.5	76.0	122.8
2 :55	95.0	.140	2:50	2150	9.30				
2:59		.260	2:55	2200	9.40				
			3:00	2210	9.30	442.0	63.7	78.5	125.5
⑥									
3:07	100.0	.160	3:05	1750	10.40	182.0	64.0	78.1	126.8
3:12		.330	3:10	1870	10.40				
3:16	100.0	.100	3:15	2050	10.25		63.7	77.8	126.0
3:20		.250	3:20	2200	10.00				
3:23	100.0	.125	3:25	2240	9.60		63.5	78.0	127.5
3:28		.308	3:30	2500		435.0			
⑦							(Brake hot)		
3:43	105.0	.195	3:41	1560	10.80	169.0	62.7	78.0	125.0
3:47		.340	3:46	1380	11.10				
3:51	105.0	.185	3:51	1600	11.05				
3:55		.350	3:56	1670	11.05		61.0	77.0	128.7
3:59	105.0	.145	4.01	1720	11.10				
4:03		.310	4.06	1660	11.30				
			4:11	1700	11.00	471.5	59.0	73.3	126.0
⑧									
			4:25	1650	11.85	175.0	58.0	72.8	125.0
4:28	110.0	.125	4:30	1680	11.50				
4:34		.290	4:35	1730	11.40				
4:37	110.0	.130	4:40	1810	11.35		58.0	73.0	124.0
4:42		.273	4:45	1930	11.35	390.5			
⑨							(Hot	brake)	
4:58	115.0	.150	4:55	1570	11.95	172.0	60.4	76.0	124.8
5:03		.310	5:00	1800	11.75				
5:07	115.0	.155	5:05	1400	11.95				
5:11		.278	5:10	1560	11.70		60.7	75.7	125.0
⑩			5:15	1630	11.65	394.0			

Tests of a Spiro Turbine

A. L. Myers Log Sheet No. 3 May 3, 1913.

Barom. 29.37 Room Temp. 83 F O.Temp. Tare on Br. Sc. 5.50 lb.

Calorimeter							Temperatures		
Time	Steam Press. lb/sq.in.	W	Time	r.p.m.	Wght. on Br. Sc. lb.	Wght. on Tank Sc. lb.	Inlet °F	Outlet °F	Hotwell °F
9:55	66.0	.120	9:55	2365	8.00	160.0	59.2	67.8	109.2
10:02	68.0	.280	10:00	2345	8.00				
10:05	68.0	.115	10:05	2315	7.80				
10;11	70.0	.265	10:10	2345	8.10		59.5	68.2	110.0
			10:15	2425	8.15	304.5			
⑪									
10;36	100.0	.160	10:30	2090	10.50	163.0	58.2	72.0	121.2
10:40	102.0	.320	10:35	2070	10.50				
			10:40	2095	10.85	263.0			
⑫							(Brake hot)		
Fan No.4 Running Forward									
11:59	40.0	.125	11:50	1425		166.5	60.0	66.0	98.5
12:09	39.0	.241		1330					
				1450					
				1500			60.0	65.0	99.0
				1410					
				1490					
				1510					
①			12:10	1600		252.5	60.0	65.5	98.8
12:41	41.0	.110	12:30	1750		162.0	58.0	64.0	99.0
12:49	43.0	.210		1765					
				1820					
				1800					
				1650			58.0	64.0	99.0
				1700					
				1700					
				1710					
②			12:50	1775		256.5	58.0	64.0	99.0
12:56	45.0	.130	12:55	1975		256.5	59.0	64.0	100.0
1:06	45.0	.242		2050					
				1985					
1:07	44.0	.150		2100					
1:13	45.0	.215		2060			60.0	64.0	99.0
				2025					
				2040					
				2050					
③			1:15	2050		355.0	60.0	65.0	100.0

Tests of a Spiro Turbine

A. L. Myers Log Sheet No. 4 May 3, 1913.

Barom. 29.37 Room Temp. 83 F O. Temp.

Calorimeter						Temperatures			
Time	Steam Press. lb./sq.in.	W	Time	r.p.m.	Wght. on Tank Sc. lb.	Inlet °F	Outlet °F	Hotwell °F	Remarks
Fan No.4 Running Forward (cont'd)									
1:21	51.0	.128	1:20	2450	165.5	60.0	66.0	102.0	
1:31	50.0	.262		2455					
				2500					
1:32	50.0	.124		2540					
1:39	54.0	.220		2600		60.0	67.0	102.0	
				2435					
				2380					
				2550					
			1:40	2740	278.5	60.0	67.5	103.0	
④									
1:46	62.5	.124	1:45	3050	165.0	60.5	69.0	107.0	
1:56	62.5	.300		2830					
				2800					
1:57	62.5	.125		2950					
2:04	67.0	.258		3050		60.5	69.0	107.0	
				3060					
				2650					
				3050					
				3025					
				3050					
			2:05	3150	303.0	61.0	69.5	109.0	
⑤									
2:11	79.0	.136	2:10	3500	169.0	61.0	73.0	114.0	
2:18	78.0	.324		3500					
				3525					
2:19	79.0	.138		3550					
2:25	78.0	.310		3535		61.0	72.5	114.0	
				3500					
				3480					
				3435					
			2:30	3590	338.0	61.0	72.0	115.0	
⑥									

Tests of a Spiro Turbine

A. L. Myers　　Log Sheet No. 5　　May 3, 1913.

Barom. 29.32　Room Temp. 87 F

Calorimeter			Time	r.p.m.	Wght. on Tank Sc. lb.	Temperatures			Remarks
Time	Steam Press. lb/sq.in.	W				Inlet °F	Outlet °F	Hotwell °F	
Fan No.5 Running Forward									
2:46	49.0	.121	2:45	1750	162.0	61.0	67.5	102.0	
2:56	47.0	.211		1760					
				1650					
				1660					
				1610		61.0	67.5	103.0	
				1700					
				1690					
			3:05	1700	268.0	61.0	67.5	103.0	
①									
3:11	54.0	.130	3:10	1925	268.0	61.0	67.5	103.5	
3:21	54.0	.236		2075					
				2020					
3:23	54.0	.121		1960		61.0	67.0	103.5	
3:29	54.0	.210		2100					
				2110					
				2175					
			3:30	2175	385.5	61.0	67.5	103.5	
②									
3:36	64.0	.129	3:35	2540	185.0	61.0	68.5	106.0	
3:46	62.5	.313		2510					
				2550					
3:47	62.5	.102		2550					
3:53	62.5	.212		2535		61.0	68.5	106.0	
				2490					
				2550					
				2450					
				2325					
			3:55	2475	320.5	61.0	69.0	107.0	
③									

Tests of a Spiro Turbine

A. L. Myers　　Log Sheet No. 6　　May 3, 1913.

Calorimeter			Time	r.p.m.	Wght. on Tank Sc. lb.	Temperatures			Remarks
Time	Steam Press. lb/sq.in.	W				Inlet °F	Outlet °F	Hotwell °F	
Fan No.5 Running Forward (cont'd)									
4:04	80.0	.120	4:00	3050	168.0	61.0	70.0	110.5	
4:11	80.0	.310		3050					
				2990					
4:13	79.0	.126		3150		60.0	70.0	112.5	
4:18	81.0	.262		3000					
				3050					
				3160					
			4:20	3125	336.0				
④									
4:27	96.0	.130	4:25	3525	171.0	59.0	71.0	118.0	
4:33	96.0	.330		3445					
				3475					
4:34	95.0	.115		3450					
4:40	96.0	.328		3500		59.0	70.5	118.0	
				3600					
				3650					
				3475					
			4:45	3425	368.5	59.0	70.5	117.0	
⑤									
Fan No. 6 Running Forward,- Throttle wide open									
4:56	121.5	.105	4:55	3150	162.5	60.0	75.0	124.0	
5:06	112.5	.340		3120					
				3150					
5:08	113.5	.108		3100					
5:14	115.0	.270		3050		60.0	75.0	125.0	
				3025					
				3125					
				3075					
			5:15	3050		60.0	76.0	126.0	
⑤									

Tests of a Spiro Turbine

A. L. Myers Log Sheet No. 7 May 5, 1913.

Barom. 29.4 Room Temp. 85 F

Calorimeter			Time	r.p.m.	Wght. on Tank Sc. lb.	Temperatures			Remarks
Time	Steam Press. lb/sq.in.	W				Inlet °F	Outlet °F	Hotwell °F	
Fan No.6 Running Forward									
2:12	60.0	.105	2:10	1540	161.0	58.5	67.0	106.0	
2:24	53.0	.315		1610					
				1550					
2:25	54.5	.135		1575					
2:29	53.0	.202		1660		58.5	67.0	105.0	
				1550					
				1525					
				1590					
			2:30	1610	279.5	58.5	67.0	104.5	
①									
2:36	65.0	.115	2:35	1825	166.5	58.0	68.0	108.5	
2:43	63.0	.300		1855					
				1850					
2:44	62.5	.128		1800					
2:50	66.0	.305		1775		59.0	69.0	108.5	
				1900					
				1910					
				1900					
			2:55	1875	303.0	60.5	70.5	110.5	
②									
3:01	76.0	.125	3:00	2310	167.5	61.0	72.0	115.0	(Barom. 29.392)
3:06	76.0	.295		2260					
				2225					
3:07	76.0	.126		2200					
3:12	79.0	.318		2290		61.0	72.0	116.0	
				2400					
3:14	76.0	.118		2280					
3:19	74.0	.287		2250					
			3:20	2250	330.0	61.0	72.0	115.0	
③									
3:26	98.5	.140	3:25	2725	167.5	61.0	75.5	124.0	
3:30	98.5	.330		2715					
				2710					
3:31	98.0	.110		2700					
3:36	98.0	.345		2740		61.0	76.0	125.5	
				2640					
3:37	97.5	.150		2710					
3:43	99.0	.305		2650					
				2660					
			3:45	2690	367.5	60.5	76.0	126.0	
④									

Tests of a Spiro Turbine

A. L. Myers | Log Sheet No. 8 | May 7, 1913.

Barom. 29.5   Room Temp. 78 F   O. Temp. 70 F   Tare, Br.Sc. 5.07 lb.

Calorimeter			Time	Wght. on Br. Sc. lb.	Wght. on Tank Sc. lb.	r.p.m.	Temperatures			Remarks
Time	Steam Press. lb./sq. in.	W					Inlet °F	Outlet °F	Hotwell °F	
3:27	98.0	.110	3:25	8.0	162.0	4700	57.0	69.0	120.0	Brake
			3:30	8.0	215.0	5000				
						4000				
			3:35	8.0	265.0	4740	56.5	69.0	121.0	
			3:40	8.0	315.0	5100				
						3850				
			3:45	8.0	365.0	4700	56.5	69.0	120.0	
						3560				
3:48	95.5	.320				4500				
			3:50	8.0	415.0	4550	56.5	69.0	121.0	
						4800				
⑬			3:55	8.0	468.0	4950				

Tests of a Spiro Turbine · Result Sheet · A. L. Myers · May, 1913

Trial	Atmospheric Press. lb./sq. in.	~ Temperatures ~ °F					Average Steam Pressure lb./sq. in. Ga.	Average Steam Pressure lb./sq. in. Absolute	Quality of Steam	% Moisture in Steam	Rev. per Min. (Av.)	Brake Horse Power	Water Rate (based on dry steam)
		Room	Outside	Av. Inlet, Circulating Water	Av. Outlet Circulating Water	Av. Hotwell							
Prony Brake													
1	14.47	81.0	80.0	57.0	63.0	98.4	47.25	61.72	.947	5.3	1800	.56	547
2				57.0	64.0	101.6	57.25	71.72	.942	5.8	1524	1.26	314
3				57.0	65.8	105.8	67.75	82.22	.944	5.6	1963	1.87	220
4				57.0	67.6	110.7	78.35	92.82	.945	5.5	2286	2.78	164
5				57.0	68.0	114.2	88.00	102.47	.944	5.6	2350	3.45	149
6	14.43	86.5	84.0	62.4	76.0	121.7	93.00	107.43	.955	4.5	2076	3.20	167
7				63.7	78.0	126.8	98.30	112.73	.950	5.0	2102	3.83	151
8				60.9	76.1	126.6	103.50	117.93	.947	5.3	1613	3.51	163
9				58.0	72.9	125.5	108.50	122.93	.963	3.7	1760	4.12	147
10				60.5	75.8	124.9	113.50	127.93	.960	4.0	1592	3.91	163
11	14.40	83.0		59.3	68.0	109.6	65.50	79.90	.952	4.8	2359	2.17	190
12				58.2	72.0	121.2	99.40	113.80	.945	5.5	2085	4.07	139
13	14.48	78.0	70.0	56.5	69.0	120.5	94.70	109.18	.985	1.5	4537	5.07	119
Blast Wheel No. 4													
1	14.40	83.0		60.0	65.5	98.7	36.5	50.9	.964	3.6	1467	.40	622
2				58.0	64.0	99.0	39.0	53.4	.963	3.7	1741	.50	546
3				60.0	64.0	100.0	41.9	56.3	.967	3.3	2037	.60	472
4				60.0	67.0	102.0	48.4	62.8	.965	3.5	2517	1.12	294
5				60.5	69.0	108.0	60.6	75.0	.960	4.0	2969	2.01	198
6				61.0	72.5	114.0	77.0	91.4	.952	4.8	3513	3.18	152
Blast Wheel No. 5													
1				61.0	67.5	103.0	45.2	59.6	.976	2.4	1690	.60	518
2				61.0	67.5	103.5	51.2	65.6	.970	3.0	2068	.90	380
3				61.0	68.5	106.0	60.2	74.6	.961	3.9	2498	1.70	230
4	14.38	87.0		60.0	70.0	111.7	78.4	92.78	.953	4.7	3197	3.50	138
5				59.0	70.5	118.0	93.8	108.18	.950	5.0	3505	4.70	120
Blast Wheel No. 6													
1	14.43	85.0		58.5	67.0	105.0	52.3	66.73	.960	4.0	1580	.65	525
2				59.0	69.0	109.0	61.5	75.93	.942	5.8	1855	1.05	368
3	14.40	85.0		61.0	72.0	115.0	74.6	89.00	.938	6.2	2274	2.30	198
4				61.0	76.0	125.0	96.4	110.80	.943	5.7	2694	4.20	135
5				60.0	75.0	125.0	114.1	128.48	.968	3.2	3094	5.85	118

Sample Calculations.

Trial 13, Prony Brake:

Item 1. Atmospheric press. = .491 × reading of Hg. in inches.
= $.491 \times 29.5 = 14.48$ lb./sq.in.

Item. 7. Average Steam press. = Av. Ga. press. minus correction for inaccuracy of gage.
= $96.70 - 2.00 = 94.70$ lb./sq.in.

Item 8. " Absolute " " = Av. corrected Ga. press. plus atmos. press.
= $94.70 + 14.48 = 109.18$ lb./sq.in.

Item 9. Quality of Steam, $x = \frac{\omega}{\omega + W}$, where: ω = lb. steam flowing thro orifice of calor. in 10 min.
W = lb. water collected in Calor. in 10 min.

$$x = \frac{6.50}{6.50 + .10} = .985$$

ω, corresponding to corrected Ga. press. = 6.50 lb.

$W = \frac{.21}{2.1} = .100$ lb.

Item 10. Moisture in Steam; in percent = 100 (1 − quality)
= $100\,(1 - .985) = 1.5$

Item 12. Brake horse power, = $\frac{2\pi WLN}{33000}$, where L = length of brake arm in ft. and brake constant = $\frac{2\pi L}{33000}$
= $\frac{2 \times 3.1416 \times 2}{33000} = .000381$

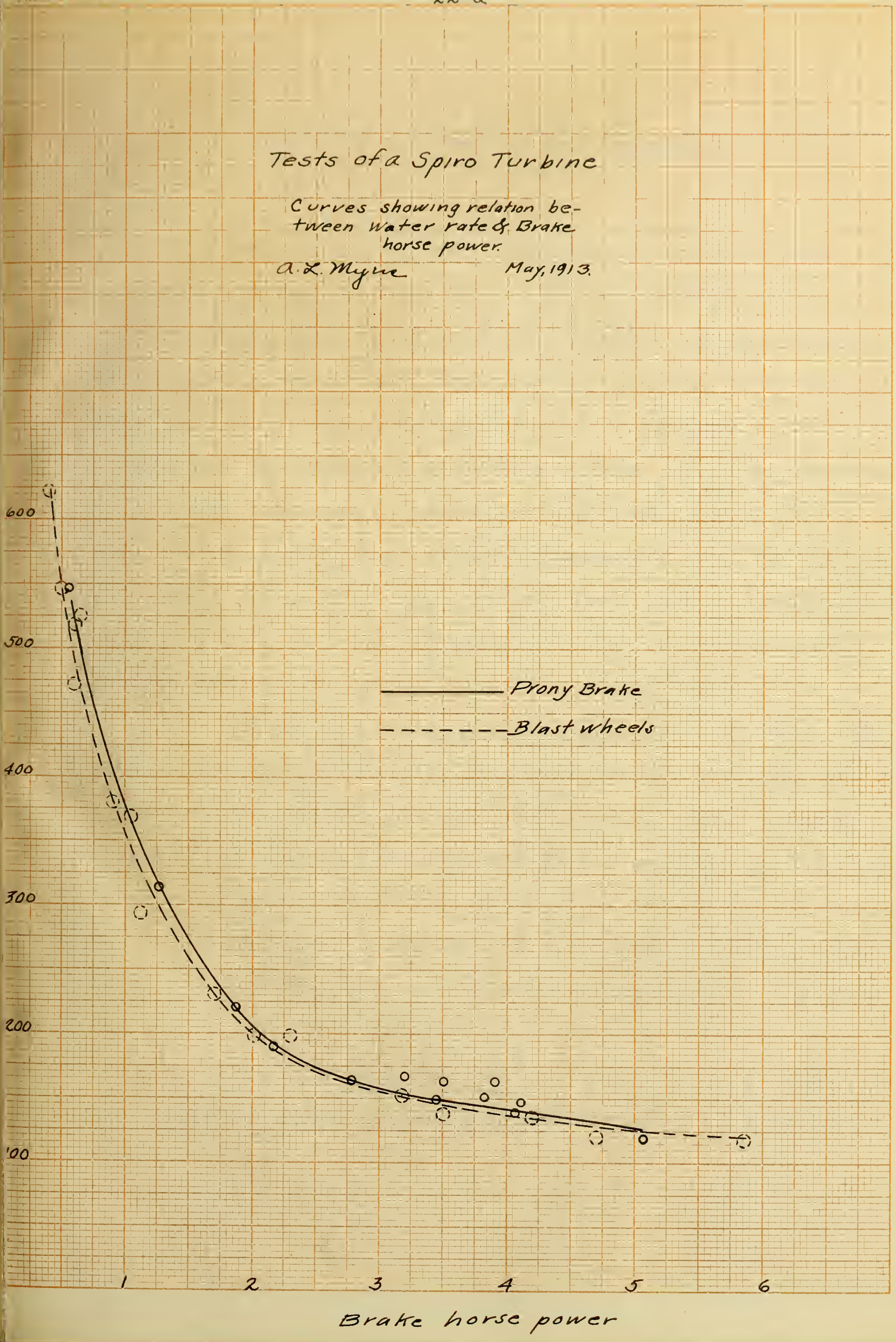
$$= .000381 \times 2.93 \times 4537 = 5.07$$

W = net wght. on brake Scales
= $8.00 - 5.07 = 2.93$ lb.
N = r.p.m. = 4537

Item 13. Water rate, = $\frac{\text{lb. dry steam per hr.}}{\text{B. h. p.}}$

$$= \frac{2\,(.985 \times 306)}{5.07} = 119 \text{ lb.}$$

Note: For Fan Tests, B.h.p. was obtained from calibration curves submitted by Buffalo Forge Co.



Tests of a Spiro Turbine

Curves showing relation between Water rate & Brake horse power.

A. L. Myre May, 1913.

Discussion of Results and Conclusions.

7 From a study of the curves on the opposite page, it is seen that the results from the fan tests check out those obtained from the brake tests to a surprising degree. Before the fan tests were run, the writer felt that perhaps the prony brake was not reliable for high speeds, and was the more constrained to this belief since the water rates obtained were 100% in excess of those claimed by the manufacturers. One result representing a 10 minute trial with the brake might with reason be discarded, but its removal would not affect the general slope of the curve shown. In drawing these curves, points representing values obtained at normal speeds, i.e., 2000 to 2500 r.p.m., were given the greatest weight.

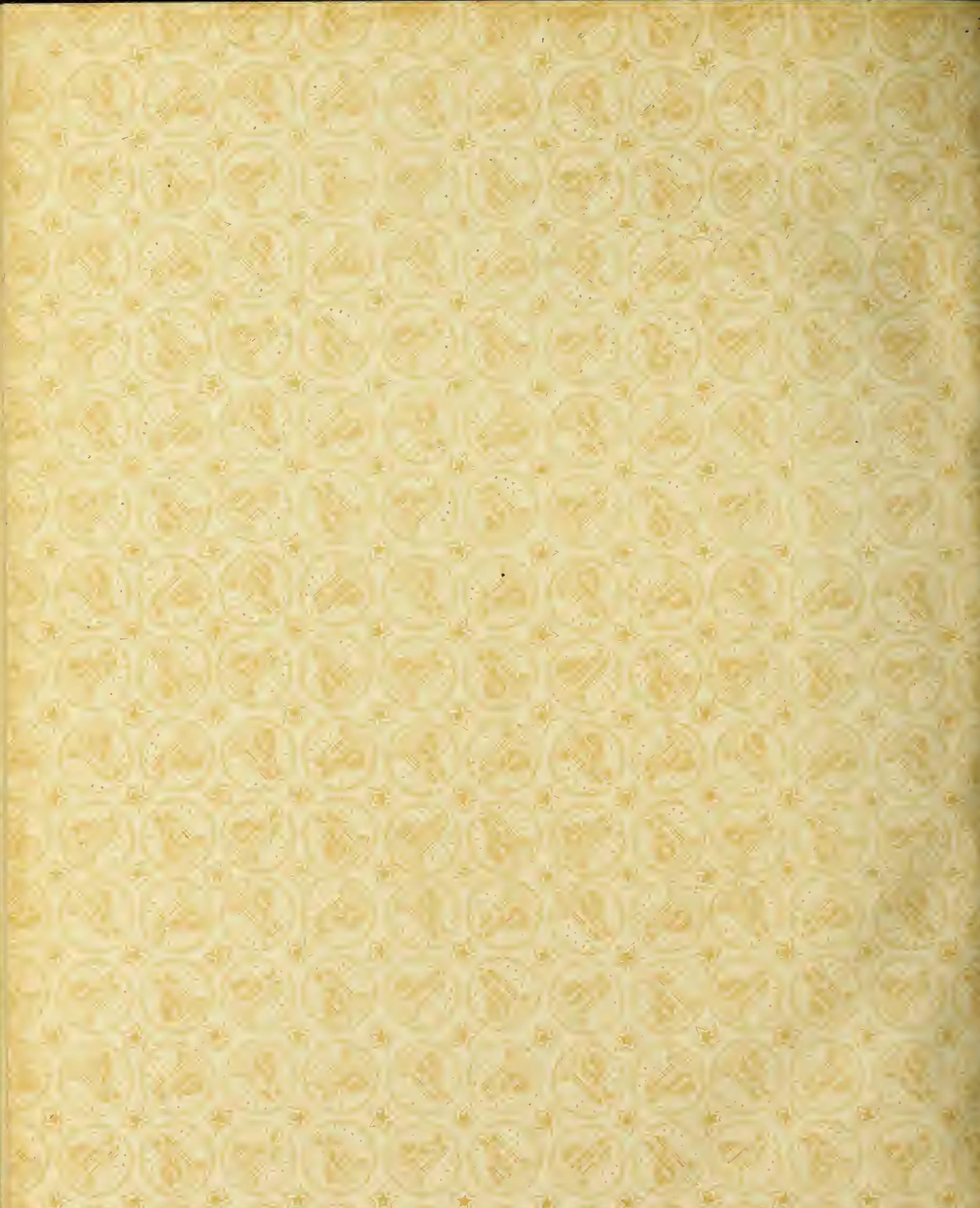
The quality of steam varied from .938 to .985. This latter value is considerably above the average obtained, and was gotten at an exceptionally high speed. It is not unreasonable to suppose that the presence of considerable moisture in the steam lessens the efficiency. The average quality during the fan tests was some better than that which obtained when the brake tests were being run, possibly due to a higher average speed. Just what affect the quality has is an interesting question.

The writer believes that the results are correct, since great care was taken in making observations and in calculating results.

It would seem then, that the statement made in Art. 2 with regard to poor economy is borne out by the results obtained. The economy of the Spiro turbine would compare with that of the steam pump or other turbines of similar capacity, and hence does not have an exceptionally low steam consumption.

Apparently, the most economical speeds are around 2000 r.p.m. and above.

Note: The writer wishes to acknowledge his indebtedness to Professors Richards and Goodenough, and Mr. Godeke, for helpful suggestions and advice.



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